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CHANGES IN THE CHEMICAL COMPOSITION OF GRAPES DURING RIPENING

BY

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The investigations reported in this paper were undertaken to determine the changes in chemical composition of vinifera varieties of grapes in California during the growing and ripening stages. A survey of the literature indicated that, although the subject had been quite fully investigated in Europe with vinifera varieties and in America with the native varieties, very little had been published upon the ripening of vinifera varieties under California Conditions. A great many analyses of different varieties of grapes have been made by chemists of the University of California Experiment Station, notably by G. E. Colby, and are reported in the publications of this station.[1] A paper by G. E. Colby[2] gives data upon the nitrogen content of a number of varieties of ripe vinifera grapes. Most of the analyses, however, do not show the changes in composition during ripening.

Of the more recent European investigations[3] some deal with the changes in general composition, others are confined to a discussion of a single component, such as sugar, or coloring matter, or acid principles.

The changes in composition of American varieties of grapes during ripening have been studied quite thoroughly by W. B. Alwood[4] and his associates. These investigations gave particular attention to the

[1] Hilgard, E. W., The composition and classification of grapes, musts, and wines. Rept. of Viticultural Work, Univ. Calif. Exper. Sta. Rep., 1887–93, pp. 3–360.

[2] Colby, G. E., On the quantities of nitrogenous matters contained in California musts and wines. *Ibid.*, pp. 422–446.

[3] Kelhofer, W., The grape in the various stages of maturity; trans. by E. Zardetti. Gior. Vin. Ital., vol. 34 (1908), no. 30, pp. 475–477.

Barberon, G., and Changeant, F., Investigations on the development and

increase in sugar content and changes in acidity during the period in which the grapes were under observation. Alwood and other members of the Bureau of Chemistry, United States Department of Agriculture, have also published a number of reports[4] on the general composition of American varieties of grapes as affected by season, locality, etc.

The most notable changes taking place during ripening were found by the European and American investigators mentioned above to be: (1) increase in total sugar; (2) decrease in ratio of glucose to fructose; (3) decrease in total acid; (4) increase in ratio of cream of tartar to total acid due to decrease in total acid; (5) decrease in tannin; and (6) increase in coloring matter. The cream of tartar and protein change very little in percentage during ripening, although, according to the

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composition of varieties of grapes in Abraon-Durso. Ann. Soc. Agr Sci. et Ind., Lyon (8), vol. 1 (1903), pp. 97–159.

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Martinand, V., On the occurrence of sucrose and saccharose in different parts of the grape. C. R. Acad. Sci. (1907), vol. 24, pp. 1376–79.

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Koressi, F., Biological investigations of the ripening of the wood of the grape. Rev. Gen. Bot., vol. 13 (1901), no. 149, pp. 193–211; no. 150, pp. 251–264; no. 151, pp. 307–325.

Brunet, R., Analysis and composition of the grape during ripening. Rev. de Viticulture, vol. 37, pp. 15–20.

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Baragolia, W. I., and Godet, C., Analytical chemical investigations on the ripening of grapes and the formation of wine from them. Landw. Jahrb., vol. 47 (1914), pp. 249–302.

Rivière, G., and Bailhache, G., Accumulation of sugar and decrease of acid in grapes. Chem. Abs. Jour. (1912), p. 1022; Jour. Soc. Nat. Hort. France (4), pp. 125–7; Bot. Cent., 1912, pp. 117, 431.

Pantanelli, Enzyme in must of overripe grapes. Chem. Abs. Jour., vol. VI (1912), p. 2447.

[4] Alwood, W. B., Hartmann, J. B., Eoff, J. R., and Sherwood, S. F., Development of sugar and acid in grapes during ripening. U. S. Dept. Agric. Bull. 335, April 11, 1916.

—— The occurrence of sucrose in grapes. Jour. Indust., vol. II, Eng. Chem. (1910), pp. 481–82.

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—— Enological Studies: the chemical composition of American grapes grown in Ohio, New York, and Virginia. U. S. Dept. Agric. Bur. Chem. Bull. 145, 1911.

—— Crystallization of cream of tartar in the fruit of grapes. U. S. Dept. Agric. Jour. Agric. Research (1914), pp. 513, 514.

Alwood, W. B., Hartmann, B. G., Eoff, J. R., Sherwood, S. F., Carrero, J. O., and Harding, T. J., The chemical composition of American grapes grown in the central and eastern states. U . S. Dept. Agric.(1916) Bull. 452.

investigations referred to, there is a slight increase in both of these constituents.

In the investigations reported in the present paper, particular attention was given to increase in total solids and sugar, decrease in total acid, and changes in protein and cream of tartar in the must or juice of the grapes. The ripening of the leaves was traced by noting the changes in starch, sugar, acid, and protein content.

Sampling.—During 1914 and 1915 samples of fruit were taken from the time the grapes had reached full size but were still hard and green until they had become overripe. During 1916 the first samples were taken shortly after the berries had set and before the seeds had formed. The last samples were taken when the grapes had become overripe. Samples of leaves were also taken in 1916 on the same dates that samplings of the grapes were made. The samples were taken at intervals of approximately one week. They were in all cases taken from the experimental vineyard at Davis.[5]

Five-pound samples of grapes were used. The grapes were picked from the first crop, except in 1914, when a comparison of the ripening of first and second crops was made. An ordinary five-pound grape basket was filled with leaves at each sampling. The samples of grapes and leaves were shipped from the vineyard to the laboratory at Berkeley, where the grapes were placed in an Enterprise fruit crusher and pressed. The juice was sterilized in bottles at 212° F. The leaves were ground in an Enterprise food chopper and sterilized at 212° F in wide mouth, air tight bottles. The samples were then reserved for chemical examination.

In 1914 it was found that there was considerable irregularity in the variation of samples from week to week. For example, instead of an increase of total solids during the periods between samplings, a slight decrease was found in a few samples. During the 1915 season it was therefore considered of interest to note what effect certain factors might have upon the composition of samples taken on the same date.

1. Effect of Age of Vine. The entire first crop from three large old vines and from three small young vines, all of the Muscat variety, was picked, crushed, and pressed. Analyses of the juices were made with the following results:

[5] The authors wish to express their appreciation of the assistance of F. C. Flossfeder, of the University Farm at Davis, who gathered most of the samples reported upon in this paper.

Table 1—Effect of Age of Vine on Balling and Acid of Must of Muscat Grapes

Vine	Balling	Acid
Small, no. 1	24.7	.67
Small, no. 2	27.7	.49
Small, no. 3	27.6	.67
Large, no. 1	22.0	.88
Large, no. 2	23.5	.75
Large, no. 3	23.6	.76
Average, small	26.7	.61
Average, large	23.0	.81
Difference	3.7	—.20

The results show rather strikingly that young vines ripen their fruit earlier than do mature vines. This fact makes it essential that samples, to be comparative, must be taken from vines of the same age.

2. Comparison of Grapes from North and South Sides of Vines. The whole first crop from three large Muscat vines was picked. The bunches from the north and south sides of each vine were kept separate. They were crushed, pressed, and analyzed for Balling and acid content.

Table 2—Comparison of Balling and Acid of Juice From Grapes Picked From North and South Sides of Vines

Vine and side of vine	Balling	Acid
1-N	21.3	.92
1-S	22.7	.84
2-N	23.5	.81
2-S	23.5	.80
3-N	23.1	.81
3-S	24.1	.71
Average, N side	22.63	.85
Average, S side	23.43	.78
Difference	.80	—.07

The tests indicate that grapes located on the south side of the vine ripen more rapidly than those on the north side. This difference is apparently due to the fact that the south side of the vine receives more heat than the north side.

3. Effect of Location of Bunch on Cane. Grapes of first crop, from canes showing two bunches each, were picked and the bunches from near the bases of the canes kept separate from those near the tip of the cane. They were crushed, pressed, and analyzed for Balling and acid.

TABLE 3—EFFECT OF LOCATION OF BUNCH ON CANE

Vine	Nearest base of cane		Nearest tip of cane	
	Balling	Acid	Balling	Acid
Muscat, no. 1, cane 1	25.1	.73	23.7	.83
Muscat, no. 1, cane 2	25.6	.79	24.8	.80
Muscat, no. 2, cane 1	25.1	.85	24.6	.87
Muscat, no. 2, cane 2	25.2	.78	24.7	.85
Muscat, no. 3, cane 1	23.0	.79	22.6	.82
Muscat, no. 3, cane 2	24.5	.73	23.8	.73
Muscat, no. 4, cane 1	24.2	.90	25.2	.90
Muscat, no. 4, cane 2	24.5	.68	23.8	.83
Tokay, cane 1	21.2	.67	21.2	.80
Tokay, cane 2	23.0	.63	22.4	.76
Sultanina, cane 1	23.3	.61	22.3	.62
Sultanina, cane 2	22.5	.61	23.0	.63
Sultana, cane 1	23.2	.78	21.6	.70
Sultana, cane 2	21.1	.90	20.0	1.20
Palomino, cane 1	25.1	.....	23.5	.....
Palomino, cane 2	22.0	.....	23.7	.....
Means	24.9	.75	23.1	.81

The data indicate that bunches at the base of the cane ripen in most cases more rapidly than those near the tip, although this relation does not always hold and may be reversed in some instances.

4. Variation in Balling Degree of Must from Bunches of Similar Appearance and Size from Same Vineyard and Gathered on Same Date. A five-pound basket of grapes of first crop and selected for similarity of color, size of bunch, and general appearance was picked from each of a number of vines in the same vineyard. Vines of similar size and appearance were chosen. Several varieties were represented in the experiment. Tests of Balling degree only were made.

TABLE 4—VARIATION IN BALLING IN MUST FROM GRAPES OF SAME VARIETY PICKED FROM DIFFERENT VINES OF SIMILAR APPEARANCE

Variety	Vine number	Balling	Mean Balling	Maximum variation
Cornichon	3	14.5	.....	.....
Cornichon	6	15.0	.....	.....
Cornichon	9	14.2	.....	.....
Cornichon	11	14.7	.....	.....
Cornichon	.....	16.1	14.9	1.9
Emperor	10	12.0	.....	.....
Emperor	11	14.5	.....	.....
Emperor	13	15.2	.....	.....
Emperor	14	15.5	.....	.....
Emperor	17	15.0	14.4	3.5
Malaga	5	18.5	.....	.....
Malaga	6	17.2	.....	.....

TABLE 4—(*Continued*)

Variety	Vine number	Balling	Mean Balling	Maximum variation
Malaga	7	19.7	.....	.....
Malaga	9	18.5	.....	.....
Malaga	11	19.2	18.6	2.0
Muscat	*	21.7	.....	.....
Muscat	*	21.1	.....	.....
Muscat	*	20.9	.....	.....
Muscat	*	21.5	.....	.....
Muscat	*	21.7	21.4	.8
Palomino	3	19.5	.....	.....
Palomino	4	21.0	.....	.....
Palomino	6	21.2	.....	.....
Palomino	7	20.7	.....	.....
Palomino	9	18.8	20.2	2.4
Sultanina	*	22.5	.....	.....
Sultanina	*	21.5	.....	.....
Sultanina	*	18.7	.....	.....
Sultanina	*	22.0	.....	.....
Sultanina	*	22.6	21.5	3.9
Tokay	*	19.8	.....	.....
Tokay	*	19.3	.....	.....
Tokay	*	18.7	.....	.....
Tokay	*	20.7	.....	.....
Tokay	*	19.5	19.6	2.0
Pedro Zumbon	7	21.5	.....	.....
Pedro Zumbon	4	21.2	.....	.....
Pedro Zumbon	6	20.6	.....	.....
Pedro Zumbon	3	18.5	.....	.....
Pedro Zumbon	5	19.8	20.3	3.0
Emperor	15	18.1	.....	.....
Emperor	8	15.8	.....	.....
Emperor	14	16.2	.....	.....
Emperor	9	16.8	.....	.....
Emperor	16	16.3	16.6	2.3
Cornichon	4	17.3	.....	.....
Cornichon	9	16.3	.....	.....
Cornichon	10	17.9	.....	.....
Cornichon	11	17.8	.....	.....
Cornichon	13	18.0	17.5	1.7
Malaga	4	18.3	.....	.....
Malaga	5	20.4	.....	.....
Malaga	6	20.0	.....	.....
Malaga	8	20.1	19.7	1.8

Mean variation, six ripest varieties	2.32
Mean variation, six least ripe varieties	2.20
Average variation, whole series	2.30

* Adjacent vines.

The data illustrate the difficulty of selecting five-pound lots of the same variety that will represent average samples.

5. Effect of Location of Berries on the Bunch. All of the bunches of the first crop were taken from two Muscat vines. The bunches were cut into top and bottom halves. These lots were crushed separately, pressed, and the juices analyzed.

TABLE 5—EFFECT OF LOCATION OF BERRIES ON BUNCH

Sample	Balling	Acid
Vine no. 1, stem end of bunch	23.6	.76
Vine no. 1, apical end of bunch	22.7	.87
Vine no. 2, stem end of bunch	21.3	.92
Vine no. 2, apical end of bunch	21.3	.93

The results show that considerable variation in composition of the berries may exist within the same bunch.

6. Effect of Thoroughness of Pressing. About ten pounds of Muscat grapes were crushed and lightly pressed. The pulp and skins left from this pressing were then thoroughly crushed and pressed a second time. The juices from the two lots were analyzed separately.

TABLE 6—EFFECT OF THOROUGHNESS OF PRESSING

Sample	Balling	Acid
First pressing	22.8	.78
Second pressing	22.8	.79

There was practically no difference between the juices from lightly and thoroughly pressed grapes of the same lot.

The data from the above six tests indicate that it is a very difficult matter to select grapes that will represent a fair average sample of the grapes to be studied. The size and age of the vine, the side of the vines, the location of the bunch on the cane, and individual vines, all affect the composition of the juice from the grapes very materially, and these factors should be taken into account when samples are taken.

Preservation of Samples and Preparation for Analysis.—In 1914 the samples of juice were preserved with $HgCl_2$, 1:1000. In 1915 and 1916 the samples were sterilized at 100° C. Before analysis the bottles were heated to 100° C for an hour to dissolve any cream of tartar which might have separated. The juices were filtered before analysis. Considerable coagulation of dissolved solids took place during sterilization.

Methods of Analysis.—The samples were analyzed by the methods in use in the Agricultural Chemistry Laboratory and the Nutrition Laboratory of this station. A brief description of the methods follows:

1. Total Solids. The juice was filtered clear and cooled below 15° C. The specific gravity was determined by a pycnometer at 15°.5 C. The corresponding total solids, or extract, was found from Windisch's tables in Leach's *Food Analysis,* page 697. This table gives the extract as "grams per 100 grams"; that is, per cent by weight. To calculate the corresponding grams per 100 c.c., the per cent by weight was multiplied by the specific gravity. This gives a figure not very much greater than grams per 100 grams in juices of low specific gravity, but gives a figure as much as 2 per cent greater where the total solids are much above 20 per cent. The two methods of reporting total solids has in the past led to much unnecessary confusion. It is therefore urged that the reader bear in mind the distinction between the two methods when reading the discussions in this paper or examining the curves.

2. Sugar. The sample was filtered; an aliquot was treated with lead acetate; diluted to mark; filtered; lead removed with anhydrous Na_2CO_3, and the sugar determined in an aliquot by the gravimetric method, using Soxhlet's modification of Fehling's solution. The Cu_2O was weighed directly after drying at 100° C. The corresponding sugar as invert sugar was obtained from Munson and Walker's table in Leach's *Food Analysis.* The grams of invert sugar per 100 c.c. found in this way was divided by the specific gravity of the must to obtain the corresponding grams per 100 grams of juice.

3. Total acid was determined by titration of a 10 c.c. sample with N/10 NaOH, using phenolphthalein as an indicator, and is reported as tartaric acid, grams per 100 c.c.

4. Cream of tartar was estimated by a method suggested by Professor D. R. Hoagland of the Division of Agricultural Chemistry. Ten c.c. of the juice was incinerated at a low heat in a muffle furnace until well carbonized, but not to a white ash. (Excessive heating results in loss of K by volatilization.) The K_2CO_3 formed by incineration was leached out with hot water and a known excess of N/10 HCl added. This was titrated back with N/10 NaOH, using methyl orange as an indicator. The K_2CO_3 is obtained by difference and calculated back to cream of tartar, assuming that all of the K_2CO_3 is formed by the oxidation of cream of tartar, $KH(C_4H_4O_6)$. It is

reported as grams $KH(C_4H_4O_6)$ per 100 c.c., and also as tartaric acid.

5. Free Tartaric Acid was obtained by difference between total acid and cream of tartar calculated as tartaric acid. It is reported as grams per 100 c.c.

6. Protein in the juice was determined by the usual Kjeldahl-Gunning method upon a 10 c.c. sample. It is reported as grams per 100 c.c.

7. Moisture in the leaves was determined by drying the sample at 100° C.

8. Sugar in the leaves was estimated by leaching the dried sample with cold water and determining sugar by the gravimetric Fehling method in the filtrate.

9. Starch in the leaves was determined by hydrolysis of the dried ground sample with dilute HCl at 100° C., followed by filtration and the usual gravimetric Fehling method for juice described above.

10. Protein in the leaves was determined by the Kjeldahl-Gunning method on .5 gram samples.

11. Acid in the leaves was estimated by leaching in hot water and titrating in the presence of the leaves, using litmus paper as indicator.

Analyses of Musts from Grape-Ripening Samples, 1914, 1915, 1916. The data from the analyses have been assembled in the following tables. Owing to the size of the tables, abbreviations have been necessary for the headings of the columns.

Explanations of Headings of Tables

1. Sp. gr. = Specific gravity at 15°5 C.
2. T. S. G. = Total solids in grams per 100 grams.
3. T. S. C. = Total solids in grams per 100 c.c.
4. S. G. = Sugar in grams per 100 c.c.
5. S. I. = Sugar in grams per 100 grams.
6. Tl. A. = Total acid in grams per 100 c.c.
7. C. T. = Cream of tartar in grams per 100 c.c.
8. C. T. T. = Cream of tartar as tartaric acid, grams per 100 c.c.
9. T. A. = Total free acid as tartaric obtained by subtracting cream of tartar as tartaric from total acid as tartaric.
10. P. = Protein, grams per 100 c.c.
11. S. = Sum of sugar, cream of tartar, tartaric acid, and protein in grams per 100 c.c.
12. T. S. —S. = Total solids (T. S. C.) —S (preceding column).

TABLE 7—GRAPE RIPENING TESTS, 1914

(Grapes from Davis)

Malaga

First crop:

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. S. S.
Aug. 19	1.0396	10.25	10.65	7.32	7.04	2.78	.35	.13	2.65	.21	10.53	.12
Aug 26	1.0413	10.69	11.13	7.84	7.53	2.65	.36	.14	2.51	.25	10.96	.17
Aug. 26	1.0595	15.42	16.33	13.37	12.62	.77	.48	.19	.58	.55	14.98	1.41
Aug. 26	1.0613	15.87	16.84	14.31	13.50	1.46	.31	.12	1.34	.33	16.29	.55
Aug. 26	1.0694	18.01	19.25	16.59	15.52	1.00	.36	.14	.86	.38	18.19	1.06
Aug. 31	1.0732	19.00	20.39	17.65	16.45	.87	.55	.22	.65	.45	19.30	1.09
Sept. 23	1.0736	19.10	20.50	17.83	16.60	.74	.38	.15	.59	.52	19.32	1.18
Oct. 5	1.0965	25.12	27.54	24.89	22.70	.72	.50	.20	.52	.57	26.48	1.06
Second crop:												
Aug. 10	1.0213	5.51	5.62	2.07	2.03	3.22	.23	.09	3.13	.17	5.60	.02
Aug. 31	1.0495	12.82	13.45	9.58	9.13	2.51	.40	.16	2.35	.28	12.61	.84
Sept. 14	1.0532	13.78	14.51	11.89	11.30	2.07	.37	.15	1.92	.31	14.49	.02
Sept. 23	1.0670	17.43	18.60	15.29	14.33	1.54	.50	.20	1.35	.29	17.43	1.17
Sept. 23	1.0869	22.59	24.55	22.04	20.19	1.07	.45	.18	.89	.41	23.79	.76
Oct. 5	1.0930	24.20	26.45	23.90	21.87	.94	.48	.19	.75	.41	25.54	.91

Tokay

First crop:

Aug. 2	1.0454	11.75	12.28	8.73	8.35	2.63	.46	.18	2.45	.32	11.96	.32
Aug. 10	1.0624	16.08	17.08	14.28	13.44	1.56	.45	.18	1.38	.27	16.38	.70
Aug. 19	1.0682	17.69	18.90	15.94	14.92	1.32	.45	.18	1.14	.27	17.80	1.10
Aug. 31	1.0849	22.09	23.97	21.87	20.16	.63	.59	.23	.40	.40	23.26	.71
Sept. 4	1.0865	22.49	24.44	22.21	20.44	.77	.43	.17	.60	.32	23.56	.88
Sept. 4	1.0912	23.72	25.88	23.44	21.48	.59	.64	.25	.44	.41	24.93	.95
Sept. 23	1.0937	24.38	26.66	24.15	22.08	.58	.49	.19	.30	.39	25.33	1.33
Oct. 14	1.0991	25.80	28.36	25.55	23.25	.45	.54	.21	.24	.45	26.78	1.58
Oct. 14	1.1000	26.04	28.64	25.78	23.44	.52	.58	.23	.29	.58	27.23	1.41
Second crop:												
Aug. 19	1.0657	17.04	18.16	15.03	14.10	1.91	.50	.20	1.70	.32	16.55	.61
Sept. 14	1.0701	18.19	19.47	16.68	15.59	1.29	.52	.21	1.11	.33	18.64	.83
Sept. 23	1.0769	19.95	21.48	19.22	17.85	1.01	.48	.19	.82	.40	20.92	.56
Oct. 14	1.0911	23.70	25.86	23.43	21.47	.69	.60	.24	.45	.40	24.88	.98

TABLE 8—GRAPE RIPENING TESTS, 1915

(Grapes from Davis)

Cornichon

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. S. S.
Aug. 22	1.0324	8.38	8.65	3.99	3.86	3.05	.58	.23	2.82	.38	7.77	.88
Sept. 1	1.0514	13.31	13.99	10.70	10.18	1.62	.61	.25	1.37	.42	13.10	.89
Sept. 15	1.0688	17.85	19.08	15.94	14.91	.97	.70	.28	.69	.43	17.76	1.32
Sept. 22	1.0723	18.76	20.12	16.97	15.83	.94	.71	.28	.66	.46	18.80	1.32
Sept. 29	1.0737	19.13	20.54	18.31	17.05	.87	.75	.30	.61	.66	20.33	.21
Oct. 7	1.0781	20.28	21.86	19.41	18.02	.71	.73	.29	.42	.48	21.04	.82
Oct. 14	1.0843	21.91	23.76	20.40	18.81	.78	.68	.27	.62	.66	22.36	1.40
Oct. 22	1.0873	22.70	24.68	21.06	19.37	.75	.78	.31	.44	.46	22.74	1.94

TABLE 8—(*Continued*)

Emperor

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. A. S.
Aug. 19	1.0420	10.87	11.33	6.96	6.68	2.33	.38	.15	2.18	.38	9.90	1.43
Sept. 1	1.0479	12.40	12.99	9.82	9.37	1.89	.40	.16	1.73	.62	12.57	.42
Sept. 7	1.0560	14.51	15.32	11.48	10.87	1.70	.47	.19	1.57	.54	14.00	1.32
Sept. 15	1.0632	16.37	17.40	14.88	14.00	1.40	.53	.21	1.18	.54	17.13	.27
Sept 22	1.0652	16.91	18.01	15.46	14.51	.93	.48	.19	.74	.55	17.23	.78
Sept. 29	1.0672	17.43	18.60	16.37	15.34	.91	.48	.19	.72	.66	18.23	.37
Oct. 7	1.0744	19.31	20.75	17.82	16.59	.79	.58	.23	.56	.51	19.47	1.28
Oct. 14	1.0765	19.86	21.38	18.37	17.06	.79	.59	.24	.56	.63	20.15	1.23
Oct. 22	1.0792	20.57	22.20	19.81	18.36	.75	.63	.25	.49	.66	21.59	.61
Malaga												
Aug. 19	1.0546	14.14	14.91	12.47	11.82	2.05	.36	.15	1.90	.75	15.48	.57
Aug. 25	1.0651	16.86	17.96	14.53	13.64	1.66	.46	.18	1.48	.90	17.37	.59
Sept. 1	1.0678	17.59	18.78	16.75	15.69	1.38	.44	.18	1.20	.89	19.28	.50
Sept. 7	1.0719	18.66	19.50	17.00	15.86	1.29	.44	.18	1.11	.70	19.25	.25
Sept. 15	1.0758	19.68	21.17	18.17	16.89	1.21	.62	.25	.96	.70	20.45	.72
Sept. 22	1.0760	19.81	21.32	18.39	17.09	1.18	.61	.25	.93	.74	20.67	.65
Sept. 29	1.0812	21.20	22.92	18.48	17.09	1.07	.58	.23	.84	.75	20.65	2.27
Oct. 7	1.0838	21.78	23.61	21.03	19.40	1.07	.65	.26	.81	.73	23.22	.39
Oct. 14	1.0970	25.25	27.70	24.58	22.41	.59	.83	.33	.26	.88	26.55	1.15
Muscat												
Aug. 19	1.0615	15.94	16.92	13.93	13.12	1.70	.36	.15	1.55	.70	16.54	.38
Aug. 25	1.0744	19.31	20.75	17.96	16.72	1.21	.62	.25	.96	.62	20.16	.59
Sept. 1	1.0805	20.91	22.59	19.50	18.05	.79	.63	.25	.54	.63	21.30	1.29
Sept. 7	1.0827	21.47	23.25	20.39	18.83	.76	.65	.26	.50	.66	22.20	1.05
Sept. 15	1.0917	23.85	26.04	23.49	21.52	.96	.58	.23	.73	.58	25.38	.66
Sept. 22	1.0954	24.14	26.44	24.54	22.40	.77	.62	.25	.52	.85	26.53	.09
Sept. 29	1.1048	27.30	30.16	27.01	24.45	.72	.72	.29	.44	.72	28.89	1.27
Oct. 7	1.1079	28.12	31.15	28.28	25.53	.66	.59	.23	.43	.66	29.96	1.19
Pedro Zumbon												
Aug. 19	1.0555	14.38	15.18	11.96	11.33	1.81	.68	.27	1.54	.33	14.51	.67
Aug. 25	1.0588	15.24	16.14	13.77	13.01	1.09	.57	.23	.86	.53	15.73	.41
Sept. 1	1.0642	16.64	17.71	15.61	14.67	.58	.52	.21	.37	.43	16.93	.78
Sept. 7	1.0693	17.98	19.23	16.55	15.48	.84	.48	.19	.65	.73	18.41	.82
Sept. 15	1.0708	18.37	19.67	18.17	16.97	.56	.58	.23	.33	.64	19.72	.05
Sept. 22	1.0912	23.72	25.88	23.02	21.10	.53	.87	.35	.19	.64	24.72	1.16
Sultana												
Aug. 19	1.0673	17.80	19.00	15.63	16.64	1.69	.33	.13	1.56	.32	17.84	1.16
Aug. 25	1.0746	19.37	20.82	17.96	16.71	1.44	.37	.14	1.30	.38	20.01	.81
Sept. 1	1.0815	21.17	22.90	20.26	18.73	1.14	.54	.22	.92	.50	22.22	.68
Sept. 7	1.0893	23.22	25.29	23.02	21.13	.78	.44	.18	.60	.34	24.40	.89
Sept. 22	1.0902	23.39	25.50	23.10	21.19	1.24	.50	.20	1.04	.38	25.02	.48
Sept. 29	1.0922	23.99	26.20	24.04	22.01	.80	.41	.17	.63	.42	25.50	.70

TABLE 8—(*Continued*)

Sultanina

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. A. S.
Aug. 19	1.0673	17.46	18.64	15.87	14.87	1.27	.44	.18	1.09	.42	17.82	.82
Aug. 25	1.0743	19.26	20.69	18.30	17.03	1.19	.47	.19	1.00	.37	20.14	.55
Sept. 1	1.0771	20.02	21.56	18.98	17.62	.85	.49	.20	.65	.42	20.54	1.02
Sept. 7	1.0892	23.20	25.27	22.42	20.58	.72	.80	.32	.40	.62	24.24	1.03
Sept. 15	1.0927	24.12	26.36	23.62	21.62	.79	.76	.30	.39	.45	25.22	1.14
Sept. 22	1.0984	25.62	28.14	25.71	23.41	.60	.58	.23	.37	.45	27.11	1.03
Sept. 29	1.1049	27.33	30.20	27.41	24.81	.54	.51	.20	.34	.42	28.68	1.52
Tokay												
Aug. 19	1.0598	15.50	16.43	14.41	13.60	1.74	.41	.16	1.58	.29	16.69	.26
Aug. 25	1.0676	17.54	18.73	15.63	14.64	1.24	.39	.15	1.09	.69	17.80	.93
Sept. 1	1.0757	19.65	21.14	18.17	16.89	.84	.47	.19	.66	.44	19.74	1.40
Sept. 7	1.0781	20.28	21.86	19.11	17.73	.79	.45	.18	.61	.37	20.54	1.32
Sept. 15	1.0785	20.39	21.99	19.26	17.86	.74	.48	.19	.55	.40	20.69	1.30
Sept. 22	1.0798	20.73	22.38	20.17	18.68	.59	.51	.20	.39	.36	21.43	.95
Sept. 29	1.0823	21.38	23.14	20.76	19.18	.85	.58	.23	.62	.28	22.24	.90
Oct. 7	1.0830	21.57	23.36	20.87	19.27	.69	.63	.25	.44	.42	22.36	1.00
Oct. 14	1.0851	22.12	24.00	21.53	19.84	.65	.69	.28	.38	.36	22.96	1.04
Oct. 22	1.0895	23.28	25.36	22.91	21.03	.66	.72	.29	.37	.37	24.37	.99

TABLE 9—GRAPE RIPENING TESTS, 1916

Burger

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. S. S.
June 12	1.0212	5.48	5.59	1.29	1.55	2.95	.55	.22	2.73	.44	5.27	.32
June 19	1.0195	5.04	5.88	.87	.88	2.88	.51	.21	2.67	.45	4.51	1.37
June 27	1.0220	5.69	5.82	1.25	1.28	2.94	.33	.13	2.81	.45	4.87	.95
July 7	1.0220	5.69	5.82	1.11	1.28	2.98	.49	.20	2.78	.31	4.86	.96
July 10	1.0200	5.17	5.27	.93	.95	3.32	.57	.23	3.09	.37	4.97	.30
July 19	1.0205	5.30	5.41	1.03	1.05	3.13	.55	.22	2.91	.35	4.86	.55
July 27	1.0225	5.82	5.95	1.13	1.15	2.93	.48	.19	2.74	.34	4.71	1.24
Aug. 3	1.0258	6.67	6.84	2.14	2.19	2.71	.63	.25	2.46	.40	5.68	1.16
Aug. 7	1.0330	8.53	8.83	3.36	3.46	2.67	.87	.35	2.32	.47	7.12	1.21
Aug. 16	1.0391	10.11	10.51	5.90	6.13	2.41	.95	.38	2.03	.46	9.57	.94
Aug. 23	1.0422	10.92	11.38	6.03	6.27	2.10	.98	.39	1.71	.63	9.59	1.89
Aug. 30	1.0529	13.70	14.42	9.95	10.42	1.15	1.03	.41	.74	.49	12.70	1.72
Sept. 5	1.0645	16.73	17.81	14.51	15.43	1.01	1.07	.43	.68	.61	17.79	.02
Sept. 12	1.0717	18.61	19.94	16.27	17.36	.95	.98	.39	.56	.82	19.72	.22
Sept. 20	1.0765	19.86	21.37	17.44	18.73	.87	1.06	.42	.45	.62	20.86	.51
Sept. 26	1.0808	20.99	22.68	18.48	19.99	.81	1.01	.40	.41	.83	22.24	.44
Cornichon												
June 12	1.0202	5.22	5.32	.91	.93	3.15	.64	.26	2.89	.32	4.78	.54
June 19	1.0200	5.17	5.27	.86	.88	2.96	.62	.25	2.71	.42	4.63	.64
June 27	1.0193	4.99	5.08	.84	.86	2.89	.39	.16	2.73	.56	4.54	.44
July 7	1.0201	5.19	5.29	.87	.89	2.88	.44	.18	2.70	.52	4.55	.74
July 10	1.0206	5.32	5.43	.85	.87	3.27	.54	.22	3.05	.53	4.99	.44
July 19	1.0225	5.82	5.95	1.28	1.30	3.11	.57	.23	2.88	.55	5.30	.65
July 27	1.0242	6.25	6.40	1.63	1.66	2.94	.54	.22	2.72	.44	5.26	.14
Aug. 3	1.0373	9.65	10.00	5.00	5.19	2.87	.59	.24	2.63	.56	8.97	1.03

TABLE 9—(*Continued*)

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. G.	5 S. I.	6 Tl. A.	7 C. T.	8 C. T. T.	9 T. A.	10 P.	11 S.	12 T. A. S.
Aug. 7	1.0375	9.70	10.06	5.28	5.48	2.79	.65	.26	2.53	.66	9.32	.64
Aug. 16	1.0434	11.23	11.71	6.30	6.57	2.75	1.06	.43	2.32	.53	10.48	1.23
Aug. 23	1.0635	16.47	17.51	12.19	12.96	1.85	1.06	.43	1.42	.58	16.02	1.49
Aug. 30	1.0685	17.77	18.97	14.75	15.61	1.16	1.10	.44	.72	.63	18.06	.91
Sept. 5	1.0694	18.01	19.25	15.03	16.07	.93	.90	.36	.57	.58	18.12	1.13
Sept. 12	1.0757	19.65	21.09	16.37	17.60	.87	1.14	.46	.41	.78	19.97	1.12
Sept. 20	1.0786	20.41	22.00	17.52	18.88	.84	.94	.37	.44	.59	20.85	1.15
Sept. 26	1.0828	21.52	23.30	18.52	20.03	.72	.83	.33	.39	.85	22.10	1.20
Muscat												
June 12	1.0203	5.25	5.35	.91	.93	2.93	.65	.26	2.71	.38	4.67	.68
June 19	1.0199	5.14	5.24	.70	.72	3.37	.63	.25	3.12	.44	4.91	.33
June 27	1.0210	5.43	5.54	1.33	1.36	3.33	.48	.19	3.14	.49	5.47	.07
July 7	1.0210	5.43	5.54	1.63	1.66	3.32	.54	.22	3.10	.45	5.75	.21
July 10	1.0195	5.04	5.14	1.33	1.36	3.60	.55	.22	3.38	.36	5.65	.51
July 19	1.0251	6.49	6.65	2.55	2.61	3.40	.58	.23	3.17	.49	6.85	.20
July 27	1.0308	7.97	8.22	3.56	3.67	2.67	.66	.26	2.01	.45	6.79	1.43
Aug. 3	1.0488	12.64	13.26	9.72	10.19	1.77	.68	.27	1.50	.46	12.83	.43
Aug. 7	1.0582	15.68	16.58	12.72	13.53	1.60	.73	.29	1.31	.55	16.12	.46
Aug. 16	1.0803	20.86	22.53	16.81	18.15	1.16	.94	.38	.78	.51	20.38	1.70
Aug. 23	1.0910	23.67	25.82	20.20	22.04	.82	1.04	.42	.40	.56	24.04	1.78
Aug. 30	1.0972	25.30	27.75	21.87	22.99	.65	1.21	.49	.16	.58	25.94	1.81
Sept. 5	1.1023	26.64	29.36	23.28	24.74	.60	1.17	.47	.13	.65	26.69	2.67
Sept. 12	1.1101	28.70	31.85	25.95	27.83	.56	1.35	.54	.02	.69	29.89	1.96
Sept. 20	1.1122	29.25	32.72	26.43	29.39	.68	1.56	.63	.05	.58	31.27	1.45
Sept. 26	1.1133	29.54	32.89	26.68	29.70	.56	1.39	.56	.00	.59	31.57	1.32

TABLE 10—CATAWBA GRAPE RIPENING TESTS

(Table from U. S. Dept. Agric. Bulletin 335, by W. B. Alwood)

Catawba
1912:

Variety and date	1 Sp. gr.	2 T. S. G.	3 T. S. C.	4 S. I.	5 S. G.	6 Tl. A.	7 C. T.	8 C. T. T.	9 Days
Sept. 4	1.0329	8.51	8.84	3.60	3.72	3.68	.39	.16	0
Sept. 9	1.0419	10.84	11.29	6.68	6.96	3.02	.41	.16	5
Sept. 12	1.0515	13.34	14.03	9.35	9.78	2.48	.46	.18	8
Sept. 17	1.0537	13.91	14.66	10.38	10.95	2.12	.45	.18	13
Sept. 24	1.0569	14.74	15.58	11.33	11.96	1.74	.53	.21	20
Oct. 1	1.0614	15.92	16.89	12.75	13.48	1.63	.54	.22	27
Oct. 7	1.0663	17.20	18.34	13.79	14.71	1.53	.61	.24	33
Oct. 16	1.0725	18.82	20.18	15.35	16.46	1.34	.61	.24	42
Oct. 23	1.0716	18.58	19.90	15.01	16.09	1.28	.59	.24	47
Oct. 29	1.0769	19.97	21.50	16.49	17.75	1.22	.57	.23	53
Nov. 4	1.0790	20.52	22.14	16.77	18.08	1.28	.71	.28	59
Nov. 8	1.0755	19.60	21.07	16.39	17.61	1.09	.52	.21	63

Curves of Total Solids, Sugar, Total Acid, Free Acid, and Cream of Tartar.—In order to present the data in a form in which they may be readily studied, graphs have been constructed using time in days as abscissae and the above constituents expressed in grams per 100 c.c. as ordinates. The curves represent the data for 1914, 1915, and 1916. For comparison, curves of the changes in composition of Catawba grapes reported by W. B. Alwood in the United States Department of Agriculture Bulletin 335 have been included. The acid principles have been plotted to a scale five times as great as that used for total solids and sugar in order that the variations in acidity might be more apparent.

Discussion of Graphs of Total Solids, Sugar, Total Acid, Cream of Tartar, and Free Acid.—(1) Total Solids and Sugar. The data are more complete for 1916 than for 1914 or 1915, and include the period during which the berries are growing to full size as well as the ripening period itself, during which the rapid increase in sugar occurs. The curves for 1916, therefore, are of more interest than those for 1914 and 1915. In the case of the Burger variety, total solids and sugar remained constant for approximately forty days after the tests were started. There was then a slight rise in these components for a period of about ten days. From that point on the rise in total solids and sugar was very rapid and fairly uniform. The behavior of the Cornichon was very similar.

The Muscat began ripening about ten days earlier than the Burger and Cornichon, and proceeded much more rapidly up to about the ninetieth day after the experiment was started. There was then a slowing up in the increase in total solids and sugar corresponding to the period of over-ripeness. This slower increase in total solids is also evident in the curves for Emperor, Muscat, Sultana, and Tokay for the 1915 season, and would undoubtedly show in all cases if the observations were continued sufficiently.

The effect of the season upon the rate of ripening is shown by a comparison of the Cornichon and Muscat varieties for 1915 and 1916. All varieties ripened more slowly in 1915 than in 1916, resulting in steeper curves for 1916. However, owing to the fact that sampling was started later in 1914 and 1915 than in 1916, the curves for the former two years show only the changes taking place during the latter half of the ripening period. No very close comparisons therefore can be made of the three years.

The Catawba reported by Alwood, and for which curves appear

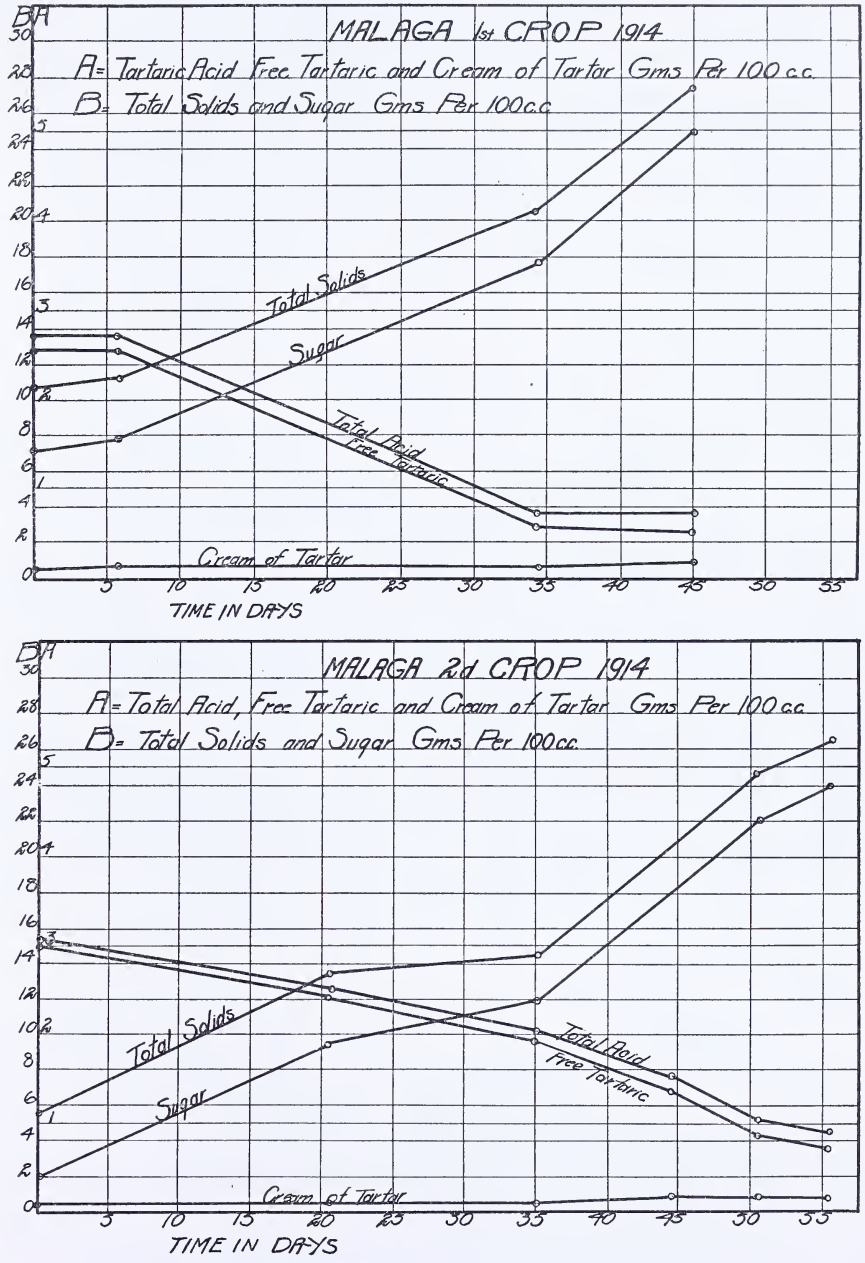

MALAGA 1st CROP 1914
A= Tartaric Acid Free Tartaric and Cream of Tartar Gms Per 100 c.c.
B= Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid Free Tartaric
Cream of Tartar
TIME IN DAYS
MALAGA 2d CROP 1914
A= Total Acid, Free Tartaric and Cream of Tartar Gms Per 100 c.c.
B= Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid Free Tartaric
Cream of Tartar
TIME IN DAYS

Fig. 1—Malaga first and second crops, 1914.

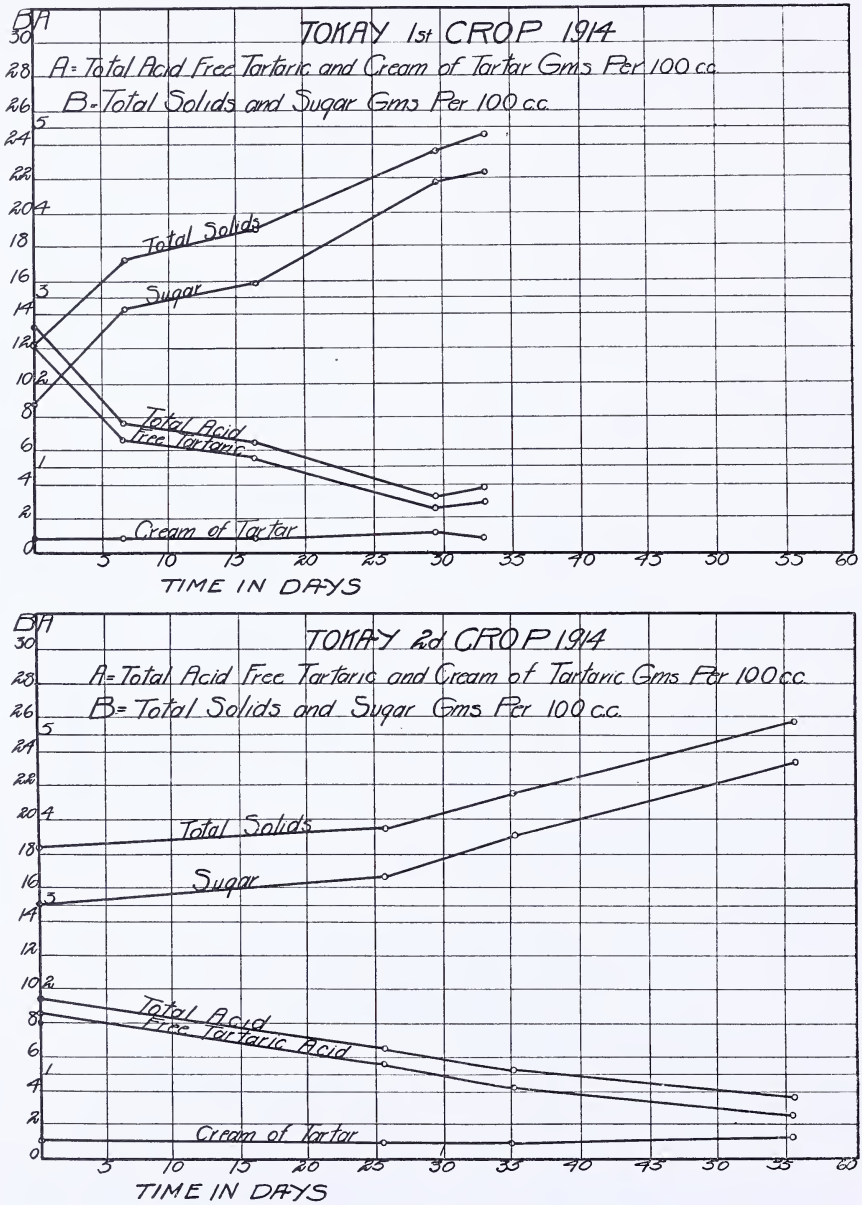

TOKAY 1st CROP 1914
A = Total Acid Free Tartaric and Cream of Tartar Gms Per 100 c.c.
B = Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid
Free Tartaric
Cream of Tartar
TIME IN DAYS
TOKAY 2d CROP 1914
A = Total Acid Free Tartaric and Cream of Tartaric Gms Per 100 c.c.
B = Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS

Fig. 2—Tokay first and second crops, 1914.

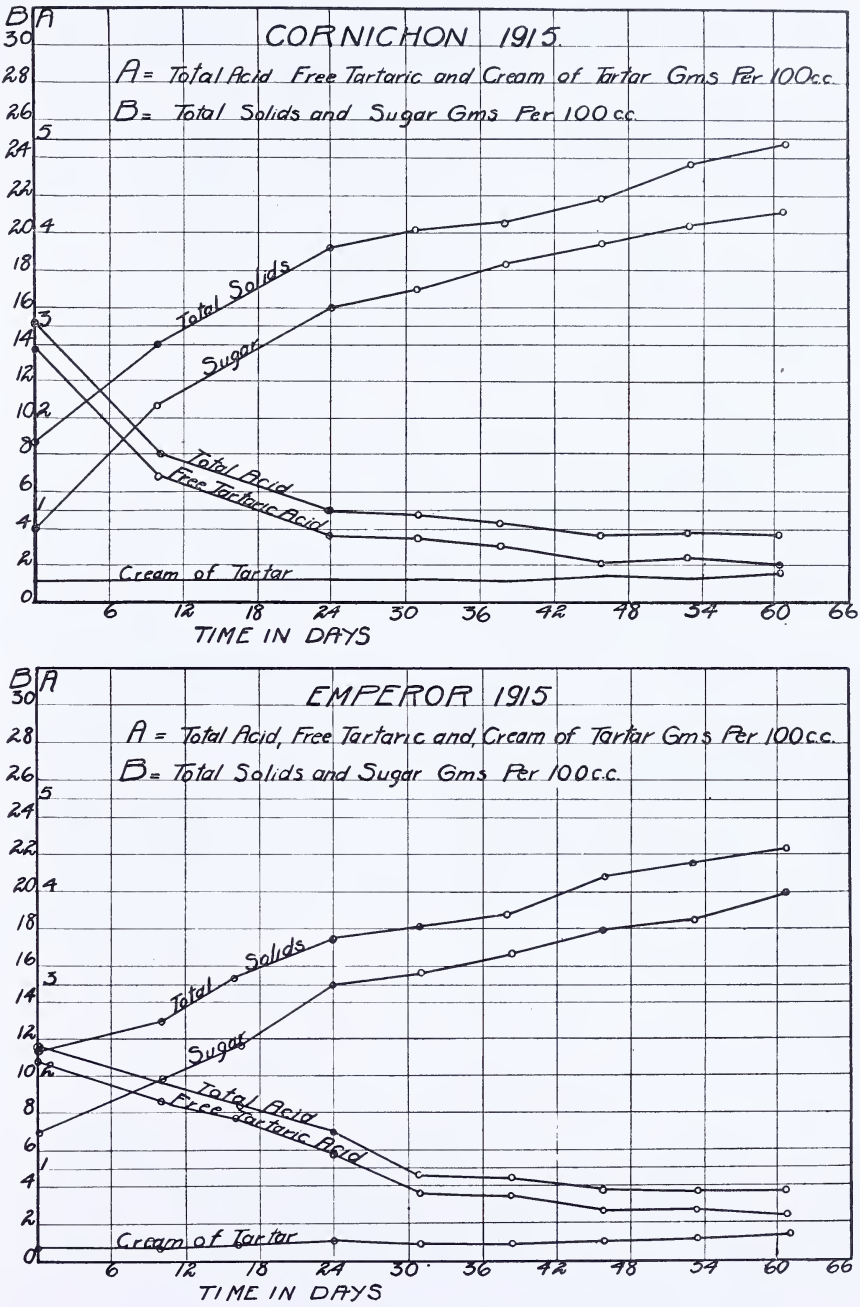

CORNICHON 1915.
A = Total Acid Free Tartaric and Cream of Tartar Gms Per 100 c.c.
B = Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS
EMPEROR 1915
A = Total Acid, Free Tartaric and Cream of Tartar Gms Per 100 c.c.
B = Total Solids and Sugar Gms Per 100 c.c.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS

Fig. 3—Cornichon and Emperor, 1915.

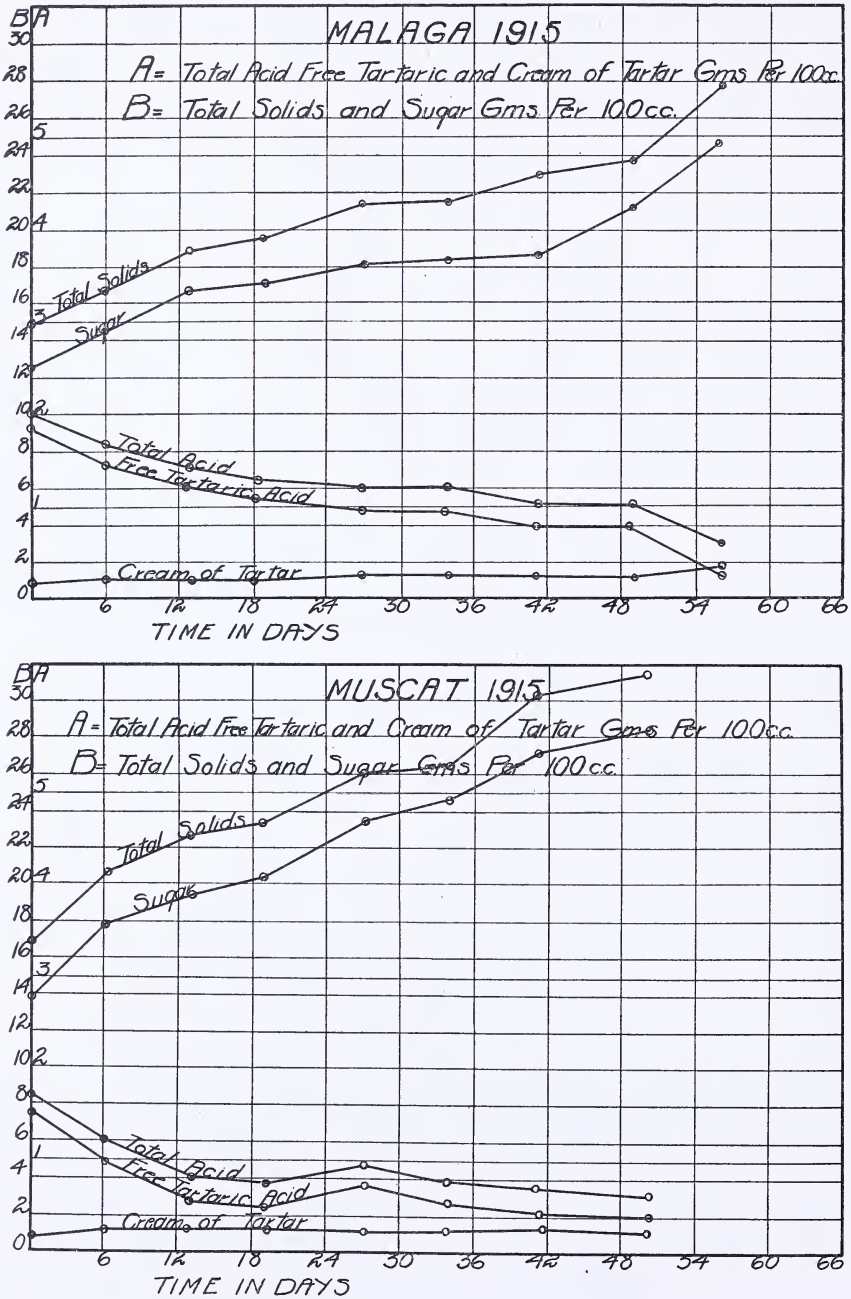

MALAGA 1915
A= Total Acid Free Tartaric and Cream of Tartar Gms Per 100cc.
B= Total Solids and Sugar Gms Per 100cc.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS
MUSCAT 1915
A= Total Acid Free Tartaric and Cream of Tartar Gms Per 100cc.
B= Total Solids and Sugar Gms Per 100cc.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS

Fig. 4—Malaga and Muscat, 1915.

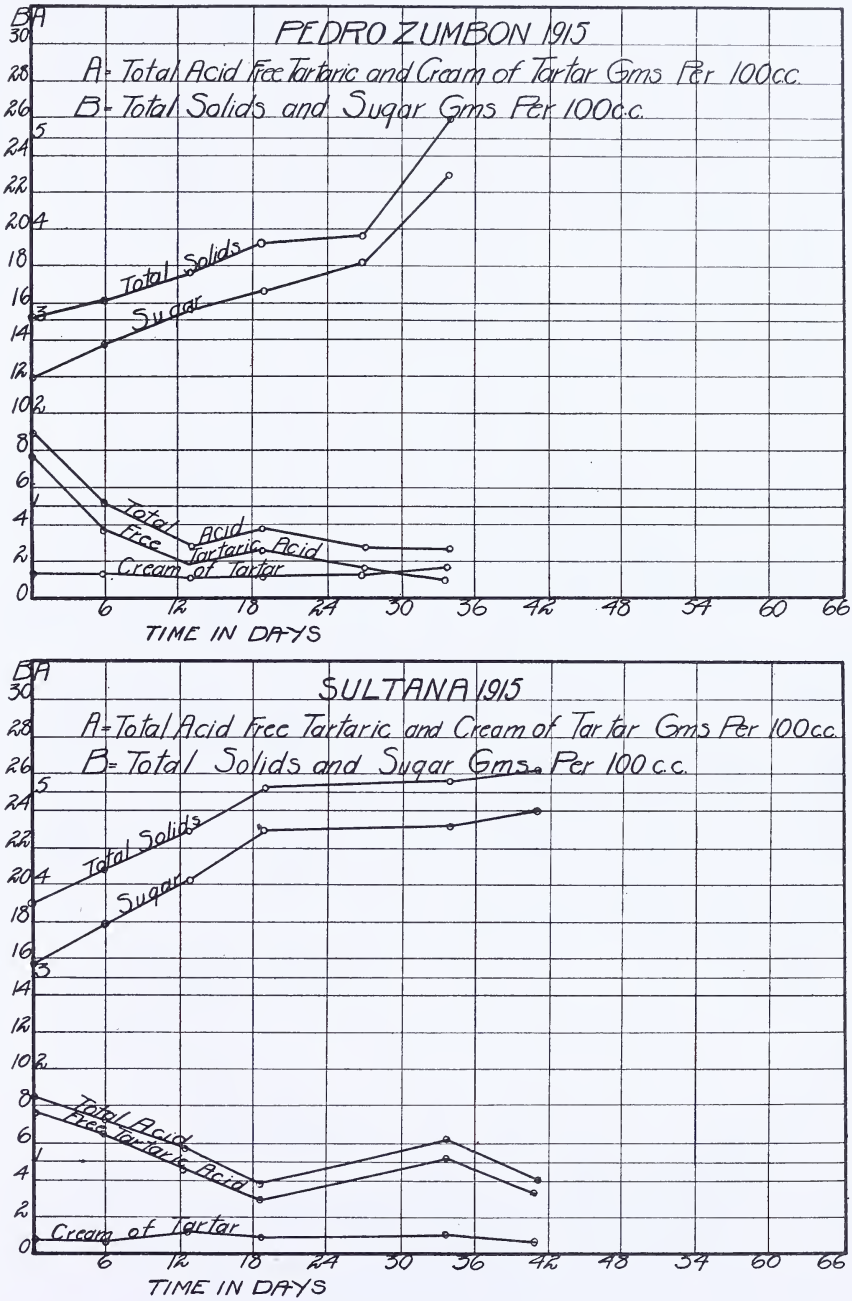
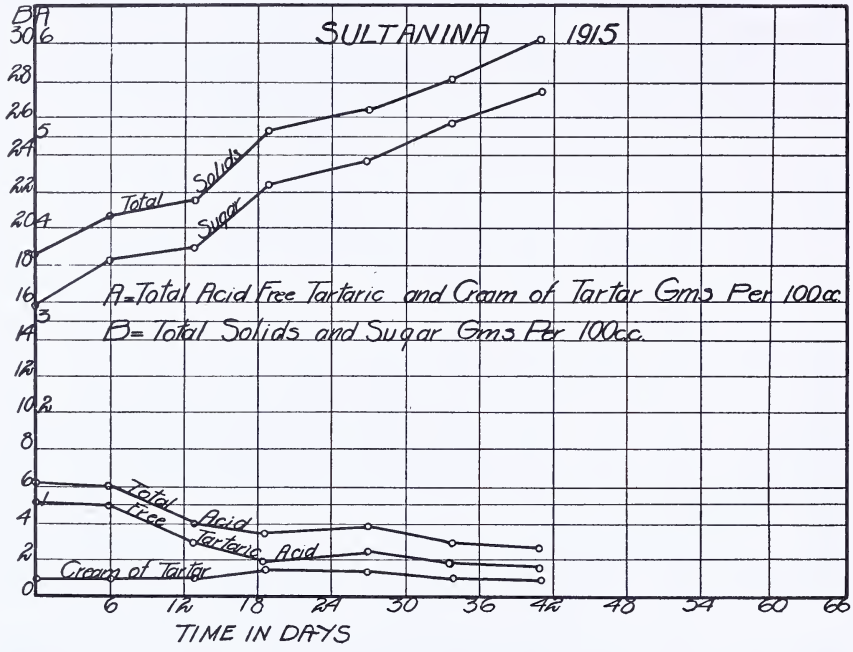

PEDRO ZUMBON 1915
A= Total Acid Free Tartaric and Cream of Tartar Gms Per 100cc.
B= Total Solids and Sugar Gms Per 100c.c.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS
SULTANA 1915
A=Total Acid Free Tartaric and Cream of Tartar Gms Per 100cc.
B= Total Solids and Sugar Gms. Per 100 c.c.
Total Solids
Sugar
Total Acid
Free Tartaric Acid
Cream of Tartar
TIME IN DAYS

Fig. 5—Pedro Zumbon and Sultana, 1915.



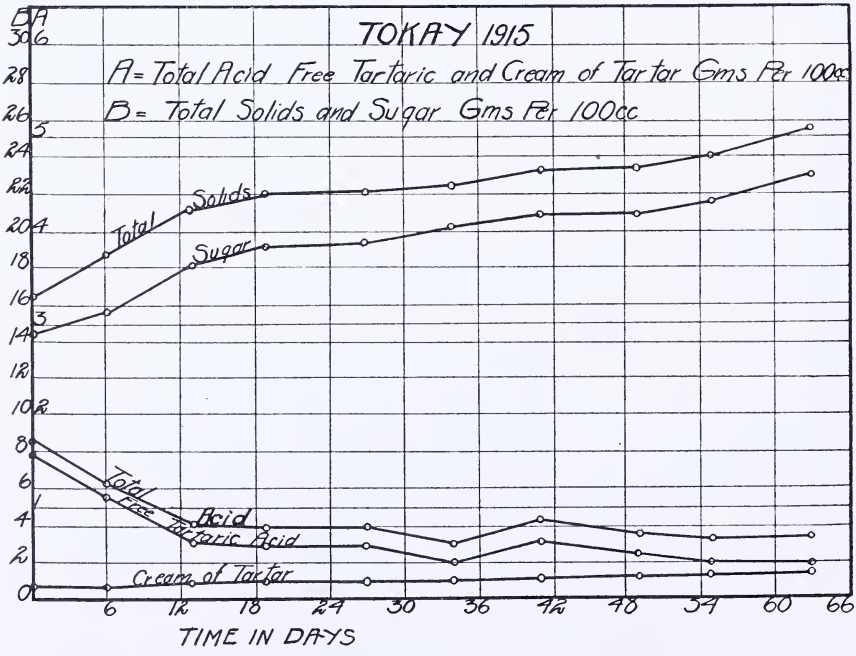

TOKAY 1915
A= Total Acid Free Tartaric and Cream of Tartar Gms Per 100cc
B= Total Solids and Sugar Gms Per 100cc
Total Solids
Sugar
Total Free Tartaric Acid
Acid
Cream of Tartar
TIME IN DAYS

Fig. 6—Sultanina and Tokay, 1915.

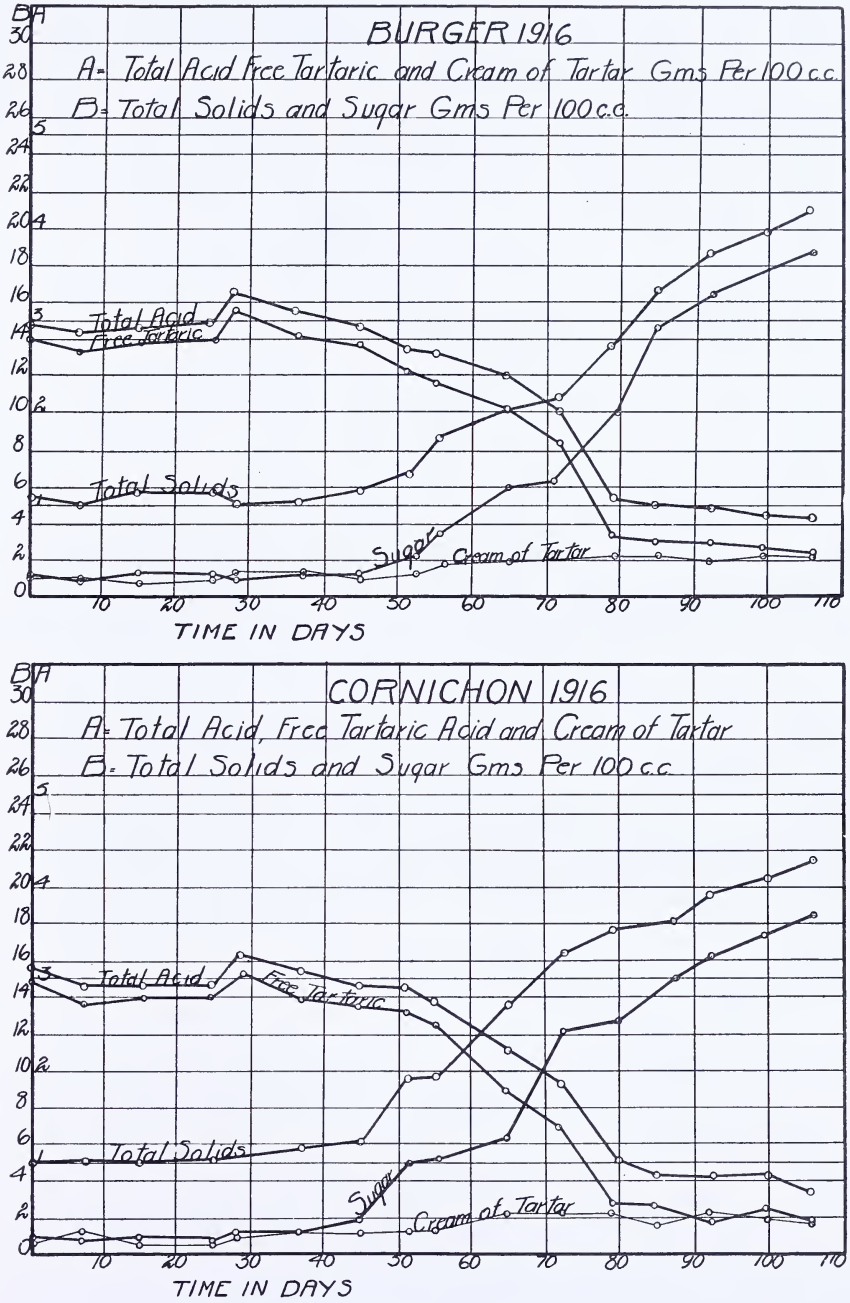


Fig. 7—Burger and Cornichon, 1916.

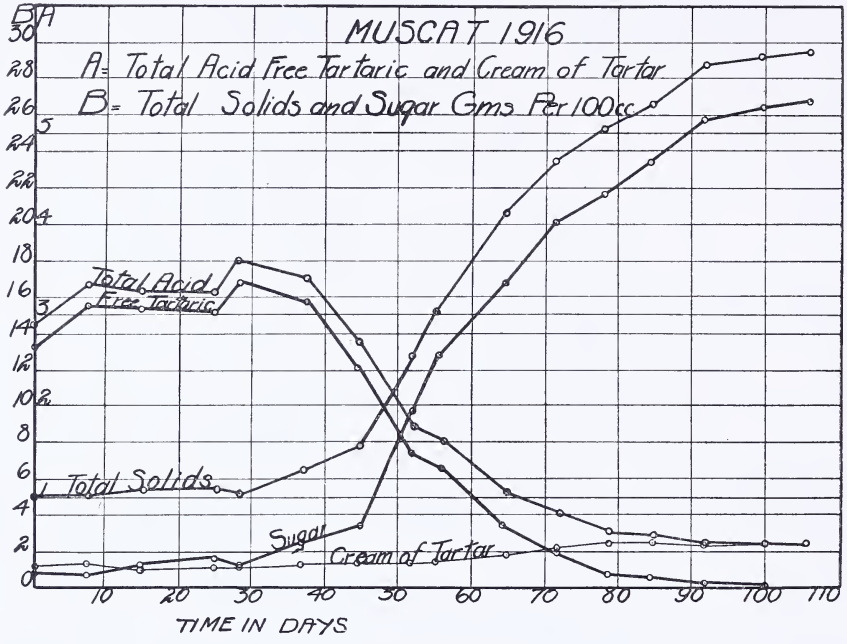


Fig. 8—Muscat, 1916.

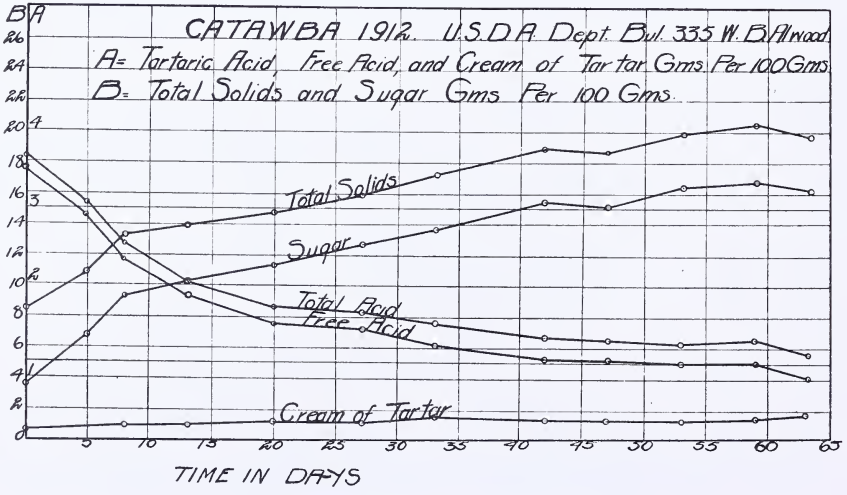

CATAWBA 1912. U.S.D.A. Dept. Bul. 335 W. B. Allwood
A= Tartaric Acid, Free Acid, and Cream of Tartar Gms. Per 100 Gms.
B= Total Solids and Sugar Gms Per 100 Gms.
Total Solids
Sugar
Total Acid
Free Acid
Cream of Tartar
TIME IN DAYS

Fig. 9—Catawba (U. S. Dept. Agric. Bull. 335).

in figure 9, ripened more slowly than the Vinifera varieties. For example, during a period of fifty days, the total solids increased only 4 per cent. It can not be said from the data at hand whether this slow ripening is due to the conditions under which the grapes were grown or to the variety.

By reference to figures 1 and 2 it may be seen that the general form of the ripening curves is the same for the first and for second crop. In one case, the Malaga, the curves are almost identical for the period common to both, i.e., from 10.6 Bal. to 26.3 Bal., showing an equal rate of ripening. In the other, the Tokay, the curve of the second crop, from 18.2 Bal. to 24.6 Bal., is much flatter than that of the first, indicating a rate of ripening with the latter of about two and a half times that of the former. This difference can be accounted for by the cooler weather during the time the second crop Tokay was ripening, which was about ten days later than in the case of the second crop Malaga. The slower ripening is probably due both to the direct effect of the cool weather and to the decreased activity of the leaves at lower temperatures.

(2) Changes in Total Acid, Cream of Tartar, and Free Acid. Owing to the fact that the analyses were started in 1914 and 1915 after ripening had commenced, the curves for these years show a decrease in acid throughout the period of the tests. In 1916, however, a rise in total acid occurred during the growing stage, as shown by a rise in the curve during the first thirty days of the experiment. Although this rise is not very large, it is quite definite, and occurs in all three varieties tested. The rise was most positive in the case of the Muscat grape, and amounted to .67 per cent acid as tartaric. From the point of maximum acidity, the total decreases slowly until the period of rapid ripening sets in. The total acid then decreases very rapidly for a time and more or less in proportion to the increase in total solids and sugar. As the grapes near maturity, the rate of decrease of total acid becomes less and the total remains practically constant after the grapes have reached maturity.

The cream of tartar in general increases very slightly during the periods of growth and ripening.

The increase in total acid during the first stages of growth is due to increase in the free acid. Since the cream of tartar remains almost constant throughout the ripening period, the curve of the free acid is practically parallel with that of the total acid.

As the grapes approach maturity, the cream of tartar calculated as

tartaric acid approaches the total acid, and in one case, (Muscat, 1916), actually became equal to the total acid, indicating that in this instance no free acid remained.

Second crop grapes were found to be higher in free acid than first crop grapes of the same total solids and sugar content. The Catawba grape grown under eastern conditions (fig. 9) exhibits relatively high free acid. Alwood[6] has found this free acidity in eastern grapes to be due largely to malic acid. No attempt was made in the analyses of the California samples to identify the various acids making up the free acidity which was calculated as tartaric acid.

Mean Differences Between Total Solids and Sugar.—The following table contains figures representing the differences between total solids and sugar at the various percentages of total solids indicated at the tops of the columns. The data represent a range of total solids from 5 per cent to 30 per cent. The figures were taken from the data reported in tables 7 to 9, and represent several varieties of grapes. Only a few determinations of total solids and sugar were available for the lower concentrations (5 per cent to 15 per cent), and therefore the figures for this range may not represent averages so accurately as the figures above 15 per cent total solids.

Between 5 per cent and 11 per cent solids, the average difference between total solids and sugar remains practically constant. From 11 per cent to 17 per cent total solids, the mean difference decreases quite rapidly. From 17 per cent to 30 per cent, the difference remains fairly constant. The variations noted after 17 per cent total solids

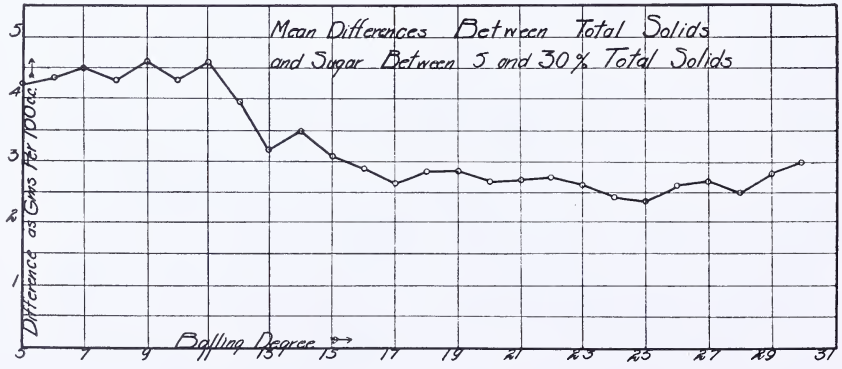


Fig. 10—Mean differences between total solids and sugar between 5 per cent and 30 per cent total solids.

[6] U. S. Dept. Agric. Bull. 335.

TABLE 11—MEAN DIFFERENCES BETWEEN TOTAL SOLIDS AND SUGAR

(Figures in columns represent difference between total solids and sugar for various juices of total solids content indicated at tops of columns)

5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
4.2	4.7	4.5	4.2	4.6	4.4	4.1	3.8	3.5	3.2	2.3	2.4	2.3	2.2	2.6	1.5	1.7	2.0	2.1	2.2	2.5	2.9	2.9	2.9	2.8	2.9
4.2	4.5	....	4.4	4.6	4.2	4.9	4.0	3.2	3.5	3.2	2.8	3.0	3.3	2.3	2.7	3.1	3.6	4.2	2.6	2.6	2.8	2.5	2.6	2.8	3.1
4.4	3.9	....	....	....	4.4	4.9	....	2.9	3.8	3.8	3.3	3.3	3.3	3.3	3.2	2.3	2.5	3.0	3.5	2.5	2.7	2.5	2.4	2.8	2.9
....	....	....	....	....	....	....	....	....	....	....	3.4	2.7	2.7	2.3	2.7	2.9	2.6	2.4	2.6	2.9	2.5	2.1	....	....	....
....	....	....	....	....	....	....	....	....	....	....	2.9	2.3	2.8	3.1	3.1	2.9	2.8	2.6	2.8	2.4	2.2	3.4	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	2.7	2.7	2.7	2.4	2.4	2.6	3.6	1.9	2.6	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	3.0	2.9	2.6	2.4	2.3	2.8	3.0	2.7	2.4	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	2.2	....	2.9	2.8	2.9	3.0	2.7	2.5	3.4	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.2	3.0	2.9	2.7	....	3.5	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.3	2.4	2.5	3.0	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.0	3.3	2.9	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.0	....	....	....	....	....	....	....	....	....
Samples:																									
3	3	1	2	2	3	3	2	3	3	3	5	8	7	11	11	12	10	9	10	9	5	5	3	3	3
Average:																									
4.26	4.33	4.5	4.3	4.6	4.3	4.66	3.9	3.2	3.5	3.1	2.88	2.69	2.84	2.85	2.69	2.73	2.76	2.62	2.43	2.37	2.62	2.68	2.50	2.8	2.96

was reached are probably within the experimental error. The large difference between the total solids and sugar noted during the first stages of ripening is no doubt due to the high acid content of the unripe grapes. The fact that the difference remains fairly constant after the grapes have become mature is to be expected, because the cream of tartar, total acid, and protein remain fairly constant as maturity is approached and during the periods of maturity and over-ripeness.

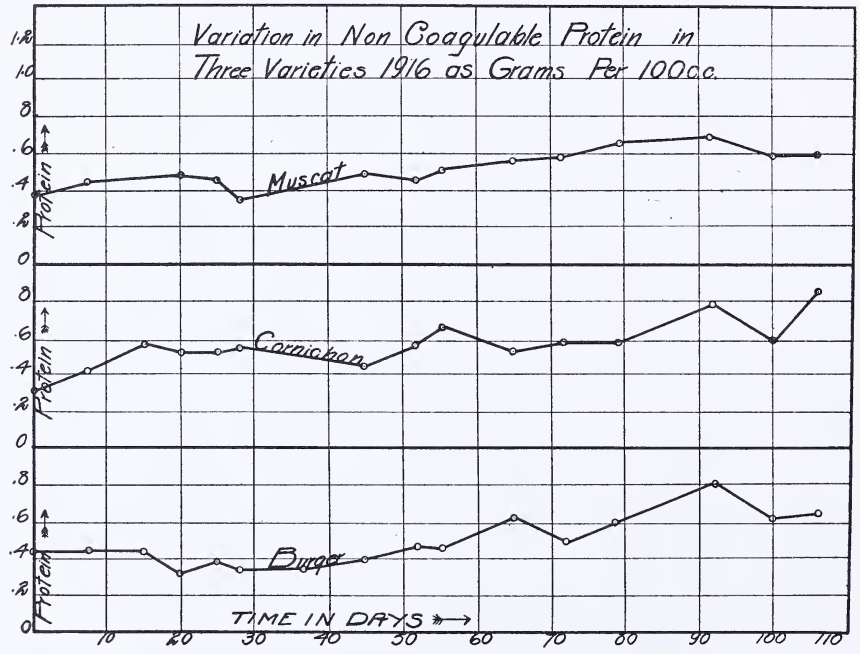


Fig. 11—Variation in non-coagulable protein content for three varieties, 1916.

Protein.—The total nitrogen content of the various samples was multiplied by 6.25 to convert it into its protein equivalent. Owing to the fact that the samples were sterilized by heat and filtered before analysis, the figures represent only the protein not coagulated by heat.

The curves show that there is a slow increase in protein content during growth and ripening and the greatest increase occurs during the period of most rapid increase of sugar and most rapid decrease of acid. The increase amounted to about .2 per cent in the case of the Muscat and .6 per cent in the case of the Cornichon. The increase seems to be quite definite, although the protein curves are not so regular as those of total solids, sugar, and total acid.

Summary of Changes in Must of Grapes During Growth and Ripening of Berries

1. *Total Solids.*—The total solids remain fairly constant during the period of growth, corresponding to the period between setting of the berries and the time at which the berries have reached almost full size but are still hard and green. From this point on, there is a rapid increase in total solids due to increase in sugar.

After the period usually considered as full maturity is reached, the increase in total solids is slow. The question may be raised as to whether this last increase is due to an actual synthesis and secretion of sugar or other solids, or simply to evaporation of water. The fact that there is no change in the curve of the acid decrease at this time indicates that the same processes are continuing and that the increased Balling degree represents an actual increase of solids. This view is fortified by observations regarding the increase of weight of solids during the ripening of raisin grapes. It has been shown that the weight of dried grapes shows a continuous increase up to the highest degree observed, 28.75 Balling.[7]

2. *Sugar.*—The total sugar during the growth period comprises only a small amount of the total solids. During ripening, the sugar rapidly increases and then constitutes a much greater proportion. During ripening, the sugar curve follows the total solids curve closely. It is more or less the mirror image of the total acid curve multiplied by five, i.e., increases as the acid decreases.

3. *Total Acid and Free Acid.*—During the early stages of the growth of the berries, the acidity increases owing to an increase of free acid. This is a fact that the authors have not found mentioned in the literature. During ripening, the total and free acid rapidly decrease. After maturity is reached, the decrease is very slow.

4. *Cream of Tartar.*—There is a very slow, but usually fairly definite, increase in cream of tartar during ripening. This increase is very much less than the decrease in free acid, and therefore can not account for any great part of this decrease.

[7] Bioletti, Frederic T., Relation of the maturity of the grapes to the quantity and quality of the raisins. Proc. Inter. Cong. of Viticulture, San Francisco, 1915, pp. 307–314.

5. *Protein.*—The protein not coagulated by heat increased definitely during growth and ripening, although the increase was not so regular nor so marked as the increase in sugar or the decrease in total acid.

6. *Difference Between Total Solids and Sugar.*—This factor remained constant for the lower percentages of total solids, decreased during the rapid ripening stage, and remained constant through maturity and over-ripeness.